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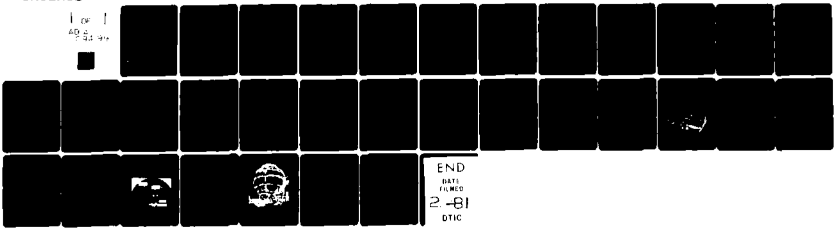

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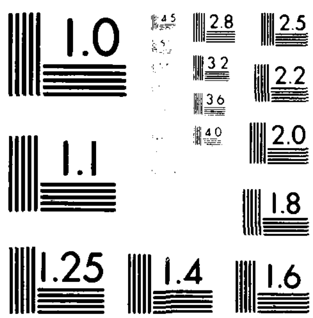

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U.S. NAVY YEARBOOK of MANPOWER, PERSONNEL & TRAINING

RESEARCH, DEVELOPMENT AND STUDY ACTIVITIES.

ARTICLES IN THIS ISSUE:

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U.S. NAVY YEARBOOK of
MANPOWER, PERSONNEL & TRAINING

RESEARCH, DEVELOPMENT AND STUDY ACTIVITIES

This Yearbook is a new venture which grew out of a request to provide an annual report to the Secretary of the Navy on the results of research in manpower, personnel and training.

The principal objective of the Yearbook is to provide the policy maker with useful information on that research. A bibliography of major research references will be a part of each article.

The Yearbook also seeks to present non-technical "state of the art" reports on research and development of current interest or significant promise, as well as to provide a forum for concepts and, to some extent, opinions. The articles do not necessarily reflect Navy policy.

Issues of the Yearbook will be published at a minimum of once a year. Recognizing that the policy maker is a busy person, we intend to limit each edition to three or four articles. The authors whose works appear in this issue were chosen for their expertise. Theirs was a difficult task. Writing for the policy maker, identifying the policy issues in the technical reports, and transforming a large body of knowledge into a concise package is a formidable undertaking. We hope you will take from this Yearbook at least one new idea or one new question. If you do, then the Yearbook has been successful.

Essays such as these should establish a dialogue between writer and reader. With that in mind, we invite your comments regarding the usefulness of the articles and your suggestions for future topics. Questions and comments may be addressed to either the Editor or the authors of the articles.

How Are We Going To Keep Them from Going Back to the Farm? Research on Personnel Loss in the Navy[1]

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I. Introduction

People leave organizations in many ways: they quit, they are fired, they retire, they move on to something else, or they become disabled or die. Turnover is a normal, everyday occurrence in all organizations, but it can be damaging if it becomes excessive.

This article addresses personnel loss in the Navy. It is presented in three sections: Section I defines attrition and retention, discusses why turnover is a problem, and presents some basic facts. Section II considers some issues related to personnel loss, and Section III discusses what an optimum turnover level should be and relates this question to an ideal force structure and to the manpower requirements of the Navy.

Some Definitions

In the Navy, personnel loss is usually talked about in two ways: *attrition*, or the loss of first term enlisted personnel prior to the end of their obligated service; and *retention*, or the Navy's ability to keep people, either officers or enlistees, beyond their initial obligations. In this article, the term "turnover" is also used to refer to the rate at which outgoing personnel must be replaced by new entrants.

Personnel loss rates are calculated in various ways. Attrition is usually expressed as a percentage of an entering cohort that left the Service at a specified interval, e.g., "recruit training attrition," "12-month attrition." Since first-termers leave the Navy for many reasons, it is possible to further refine attrition rates in terms of "reason for separation." The Department of Defense uses nine major categories, including: medical, dependency or hardship, entry into officer programs, failure to meet performance criteria, and misconduct.

Enlistee retention rates are usually expressed as the percentage of those eligible to reenlist who actually do reenlist. Such rates are calculated for first, second, and "third or more" reenlistments. Officer retention is expressed as the ratio, for a cohort, of the number on board at "minimum-service-requirement-plus-two-years" to the number on board at "minimum-service-minus-one-year." Officer retention rates are typically given by warfare community, e.g., aviation (pilot) and submarine (nuclear qualified). Since reasons for leaving after serving obligated tours are not systematically coded and recorded for either officers or enlistees, the data on this nearly 100 percent voluntary turnover are based on exit interviews, surveys, and other forms of self-reporting.

Why Is Personnel Loss a Problem?

We do not assume that turnover should be zero; some people enter the Navy who should not be there, and a certain amount of attrition is normal

[1]Title adopted from a symposium given at the ORSA/TIMS National Meeting, Milwaukee, Wisconsin, October 17, 1979, *organized and chaired by the first author.*

and desirable. There are four major reasons why attrition and failure to retain are serious problems. These factors—recruiting and training costs, turbulence, undermanning, and reduced readiness—are discussed below.

Recruiting and training costs. The cost of recruiting first term enlistees is about $2000 per recruit, an historic high. The Navy Recruiting Command works toward annual goals based on desired end strengths generated by force planners (end strengths are the numbers of people needed to man the Navy). But excessive attrition forces recruiting goals to be inflated to ensure that enough new entrants come into the system to make up for premature losses. For example, if manpower planners mandate 60,000 first-termers at the grades of E-3 to E-5 in a given year, it may be necessary to recruit up to 100,000 two to four years prior to that time because of anticipated attrition. Not only does recruiting thus become strained and very expensive, but training, particularly recruit and initial skill training, must incur excessive costs because of projected losses. Recruit training for about 94,000 entrants in FY 80 will cost $292 million; specialized skill (apprenticeship) training for about 165,000 people is budgeted at $691 million (Note 1).

Turbulence. Turbulence caused by high turnover is a problem for two main reasons. First, school seats are emptied during training when it is no longer possible to bring in replacements, resulting in inefficiency. Second, crews lose their effectiveness because teams do not continue as integral units. It is difficult to estimate the dollar costs of turbulence, but both of these conditions suggest high costs in both human and dollar terms.

Undermanning. Undermanning, a consequence of excessive personnel loss, places an unfair burden on the people remaining in the force. They are required to work harder in order to maintain a normal operating tempo, which exacerbates any dissatisfactions that may exist.

Reduced readiness. Finally, excessive personnel loss inevitably reduces the capacity of the Navy to fulfill its mission. For example, there is an alarming shortage of petty officers, whose years of growth and responsibility in their skill areas make them a valuable asset. The Navy's failure to retain these people could lead to the highest cost of all: the loss of the fleet's ability to fight. While it may be possible to improve first term recruiting to fill the gaps created by attrition, failure to retain skilled petty officers in the E-5 to E-9 grades cannot be corrected by crash programs. Such people can only be "grown"—they cannot be produced by accelerated means. The Chief of Naval Operations, Admiral Thomas B. Hayward, related the seriousness of this problem to the Secretary of Defense in 1979. He wrote, in effect, that shortages of petty officers will be the "controlling factor" in determining how many ships can go to sea ready to fight.

In summary, personnel loss—whether due to early attrition or to failure to reenlist—is probably the most serious problem facing the Navy of the 1980s. Excessive loss degrades the numbers of people in the force and serves to de-motivate and frustrate those who remain. There is no easy or fast solution to the personnel loss problem. Nevertheless, there has been considerable research on turnover, and some of it suggests directions for policy change that should be considered at the highest level. And, as with all research, new questions have been raised that can be addressed by future research and development (R&D). Those two issues—research done and research needed—are addressed in the next section. The remainder of this section provides some quantitative evidence on the state of attrition and retention.

What Is the Evidence on Attrition?

Losses of Navy male first termers during the first three years of service are now about 35 percent (slightly higher for females), having peaked at about 38 percent with men entering the Navy in FY 74. Attrition can occur at any time during a first enlistment, but it does not occur uniformly. For example, 28 percent of losses for the FY 73 cohort occurred during the first six months, and losses during each subsequent half-year through 36 months dropped from 18 percent to 9 percent of those remaining.

Why Do They Leave the Navy?

Analysis of a cohort of 94,360 males entering the Navy during the period from 1 April 1972 through 31 March 1973 showed that at the end of three years, 18,872 (20%) had completed their tours, 25,194 (27%) had been separated for "failure to meet minimal behavioral or performance criteria"; 7,360 (8%) had left for reasons of hardship, entry into officer programs, or medical conditions; and 42,886 (45%) were still serving.[2] A later cohort (April 1974-March 1975) of 89,014 showed significant increases in the numbers of those completing their enlistments (29%) and those leaving for reasons of "failure to meet minimal criteria" (32%); the proportion of entrants still serving from this more recent cohort was 31 percent (see Table 1).

Table 1
36 Month Navy Cohort Losses

	1972-73 (94,360)	1974-75 89,014)
Completed Enlistments	20%	29%
Separated:		
a) Failure to meet minimal behavioral or performance criteria	27%	32%
b) Hardship, medical, or entry into officer programs	8%	8%
Still Serving	45%	31%

Retention figures are available for ten years. Total career retention rates—including first, second, and third-term-and-beyond reenlistments—have declined from 90 percent (in FY 71) to about 66 percent (FY 80, to date). When reenlistment behavior of men in different terms is examined, the rates differ sharply; and one category, second-termers, is conspicuous because its retention rate has dropped from 77 percent to 51 percent over the ten years. The reasons given for leaving the Navy tend to be: family separation, inadequate pay, petty regulations, and dislike of sea duty (Note 2). (Recall from an earlier section that these reasons are found in questionnaire surveys and are volunteered responses.)

[2]Data in this paragraph provided by Defense Manpower Data Center.

Officer retention has been in sharp decline, particularly for certain warfare communities. For example, the surface warfare rates declined from 38 percent to 31 percent between FY 78 and FY 79; pilot retention dropped from 46 percent to 31 percent during the same interval. In some areas, retention is improving, e.g., naval flight officers' rates have increased from 54 percent to 60 percent. The reasons given by officers for leaving naval service are: civilian employment opportunities, family separation, erosion of benefits, an atmosphere of crisis management, and inadequate pay (Note 2).

II. Subjects for R&D on Attrition and Retention

A great deal of R&D has been done on attrition and retention, but many unanswered questions remain. This section describes what has been done and suggests areas that need further study. Only those results that have policy implications are presented. The interested reader should consult Hand, Griffeth, and Mobley (1977) for an excellent summary and critique of attrition research.

Navy as an Organization

Among other things, the Navy should be concerned with what recruits expect from it, what the Navy expects of recruits, and whether mismatches between the two exist. There is some evidence that a major cause of personnel loss is the failure of reality to meet expectations (Horner, Mobley, & Meglino, 1979). This gap between what new people anticipate and what they actually experience needs to be reduced.

Realistic job preview films. Two approaches to reduce recruit training attrition have resulted from research. These are the realistic job preview (RJP) and methods of coping with stress. As a result of research conducted at the University of South Carolina (Horner et al., 1979), RJP films are now shown at Marine Corps recruit training camps on a recruit's second day of training. Each film shows clearly and accurately the various tasks that a recruit will have to perform. The tasks are not made to look easy but are shown realistically, even to the extent of depicting the drill instructors and physical surroundings that the recruit will experience. Although data continue to be gathered to measure the effects of these films, to date the films seem to result in a modest reduction in recruit training attrition—from 15 percent for those not exposed to the film to 12 percent for those who are.

Similar films are being developed for the Navy. Tests on the first one at the Recruit Training Center (RTC) in San Diego started in November 1979, and results should soon be available. Twelve hundred recruits saw the film, and their progress is being compared to a control group of 1,200 who did not see the film. Tests at RTC Great Lakes are scheduled to start in February 1980, and at RTC Orlando in March 1980.

Follow-up studies on the Marine recruits involved in the original tests show some surprising long-range results. The 12-month attrition rate appears to be significantly lower for recruits who saw the film (22% vs. 33% for those who did not see it). Further research is planned to gain a better understanding as to why these long-term effects resulted from a film designed to help a recruit through basic training.

Since the realistic job preview film is shown to recruits on their second or third day in recruit training, consideration should be given to the development of some form of preview material for use with *potential* recruits. Such material could depict aspects of all the Services, and try to describe realistically their differences and similarities. It could be shown at the Armed Forces Examining and Entrance Stations (AFEES) in conjunction with the Armed Services Vocational Aptitude Battery (ASVAB) examination. Although there would be a danger of losing potential recruits by showing such material, it is also possible that those who did decide to join the military would be more likely to succeed.

A film dealing with stress coping is being tested at the Marine Corps Recruit Training Depot at San Diego (Sarason, 1977). Results are not yet available on the effect of this film on either attrition or motivation. The film is based on research at the University of Washington sponsored by the Office of Naval Research (ONR).

The authors would like to raise a point of caution. When a layman views a realistic preview film or a stress coping film, he is likely to think that much of what he has seen is obvious and to conclude that such films could be made by professional film teams without detailed input from researchers. We caution against such conclusions. These films contain many subtleties not obvious to the untrained person. To attempt to make one without the constant input of the researcher could do harm by raising expectations for reduction in attrition that are not realized. Much still has to be learned about the areas touched by the films, even by the researcher; and his analytic approach should not be circumvented until we better understand the mechanisms that are working to reduce attrition.

Commitment to the organization. An important component of retention—or non-attrition—is commitment to an organization. Relatively little is known about this. How much commitment do first-termers feel toward the Navy as a whole, and to their shipmates in particular? What practices of the Navy foster commitment or, conversely, inhibit it? With answers to these questions, it would be possible to develop or reinforce commitment.

The Naval Health Research Center (NHRC) has constructed an historical personnel data file of Navy enlistees since 1965 (Note 3). This data file was used to analyze a number of factors that relate to attrition, including demographic characteristics, personnel quality, personnel motivation and commitment, and organizational influences. Results of Phase I of the analysis, limited to demographic and quality characteristics, should be available soon. Phase II will study organizational influences.

In an attempt to obtain continuing indicators of commitment, an Enlisted Separation Questionnaire, developed at the Navy Personnel Research and Development Center (NPRDC), is being instituted. It will be given to all enlisted personnel on termination. The questionnaire asks numerous questions on attitudes and perceptions, will measure changes over time, and will serve as a systematic indicator of organizational commitment.

Turbulence. Turbulence, as mentioned earlier, is a cost of high turnover. Turbulence exists in some units more than in others—but neither its magnitude nor its effects on the Navy have been documented. Does turbulence, i.e., frequent movement by individuals among units, lead to lowered commitment and higher attrition? Is there an optimum tour length in this regard? Would turbulence be less disruptive if it included whole crews or divisions of men? Once the answers to such questions were known, turbulence could be controlled by policy decisions.

Peer influence. An organizational element that contributes to attrition or failure to remain in the career force is the influence of peers. The extent to which attrition is driven by peer pressure is not known, and should be investigated. Does attrition cause more attrition? Could the Navy turn peer influences around as a way of retaining people?

Patterns of variance. There is probably considerable variance in attrition among units or types of units. Is there more turnover, or less, in some ship types than others? Do squadrons having similar missions experience different retention rates? If so, why?

Recruiting Issues

Much effort has gone into analyzing the characteristics that differentiate those who complete their first enlistment from those who do not. Certain characteristics can be used to screen potential recruits before they enlist, in order to identify those most likely to "survive" and be useful in the Navy. Other characteristics, although of little use in initial screening, are useful in the development of counseling procedures during various stages of the first term enlistment.

Recruit screening parameters that have proven to be very valuable include age, educational level, mental group level, and number of dependents (Lockman, 1977). Educational level is the number of years of formal education, or graduation from high school. Mental group level is measured by the Armed Forces Qualification Test (AFQT). Test scores are used to rank individuals into mental groups. A combination of educational level, mental group level, age, and number of dependents is used to predict the survivability of a potential recruit through the first enlistment term. Table 2 is used by recruiters to make recruiting decisions. A potential recruit must have at least a 70 percent chance of surviving the first year of service. This table has recently been revalidated and continues to be a valuable tool.

The AFQT score that determines mental group level is derived from a subset of results of the Armed Services Vocational Aptitude Battery (ASVAB). The ASVAB is a series of 12 tests that are administered before recruitment at the Armed Forces Examining and Entrance Stations (AFEES). Three of the test scores–word knowledge, arithmetic reasoning, and space perception–are used to determine AFQT score. The remaining test scores indicate the specific skills in which the individual will be most apt, and help determine entrance eligibility into initial skill training ("A" school).

Selection techniques are the primary means by which the Navy curbs attrition while attempting to predict which individuals present a high risk for early departure. Selection testing and interviewing techniques are well established. Their present versions represent many years of R&D, and there are no major breakthroughs on the horizon. However, specialized measures for assessing certain skills (e.g., literacy) need to be developed, and more needs to be done on predicting individual motivation.

There are some attrition-prone individuals whom the Navy would like to retain, and there should be ways of identifying them early on so that they can be salvaged. Another area for research is understanding why some people succeed who, according to the predictors, should not. For example, high school dropouts are known to have a high risk of attrition–in Gunderson's 1974 cohort of 48,000 men, only 39 percent of the dropouts survived four years, versus 61 percent of the graduates (Note 3). It would be instructive to examine in depth the marginal men–about 4,900 in Gunderson's sample–who were successful sailors in spite of their nongraduate status.

Whether a recruit is assigned to a given rating or to the general detail population (GENDET) can significantly alter his or her chances of surviving the first enlistment. For example, of 15,000 Active Mariners (three-year obligated active service with three-year reserve commitment) who enlisted in 1977, 86 percent completed recruit training. These 86 percent were then assigned to "A" school or to general detail. The loss rates in the first year for these two groups were 6 percent and 14 percent, respectively. There are complex interactions here between educational level, mental level, ASVAB

Table 2
First Year Success Chances
for Recruits Entering the Navy (SCREEN)

		Years of Education							
		More Than 12		12		11		Less Than 11	
Dependent Status:		No Dep.	Dep.	No Dep.	Dep.	No Dep.	Dep.	No Dep.	Dep.
AFQT	Age								
95-100	18-19	96	94	95	93	90	87	89	84
	17	96	94	94	92	90	86	88	83
	20+	95	93	93	90	88	83	86	80
67-94	18-19	92	89	90	86	82	76	79	72
	17	92	88	89	84	81	74	78	70
	20+	90	86	87	82	78	70	74	66
50-66	18-19	91	87	88	83	79	72	76	68
	17	90	86	87	82	77	70	74	66
	20+	88	84	84	79	74	66	70	62
35-49	18-19	87	82	83	77	72	63	68	59
	17	86	81	81	75	70	61	66	57
	20+	83	78	78	71	66	57	62	52
21-34*	18-19	85	79	80	73	68	59	64	55
	17	84	78	79	72	66	57	62	52
	20+	81	74	75	68	62	52	57	48

Minimum SCREEN Eligibility

*An applicant with an AFQT range of 20 or less may not be enlisted.

scores, and rating assignment. Research efforts are continuing to better understand these relationships and meld them with the needs of the Navy.

Recent recruit shortages have led the Navy to consider recruiting from nontraditional sectors of the population. There is some evidence that older enlistees are less attrition-prone (see Thomason, 1979, for example). This should be verified. Enlisting people in their twenties raises questions for recruit training, i.e., should such training be modified? There are proposals to recruit more women and also people with minor physical disabilities; therefore there is a need for more R&D to determine the impact that those classes of people would have on turnover.

There are questions about the recruiting process itself. To what extent are recruits' expectations of service life conditioned by recruiters? Can communication between applicant and recruiter be enhanced as a way of forestalling early attrition? NPRDC has studied such questions in its PRIDE/CLASP program (Note 4). Attention to the selection and training of recruiters can bring about significant reductions in early attrition. A recruiter selection battery designed at NPRDC (Manese, Skrobiszewski, & Abrahams, 1976) is currently being implemented in the Navy. This test will be administered to all E-6s and above, and the results will be used in assigning people to recruiting duty. High test results predict increased recruiter productivity, and recruiter performance should be monitored along with subsequent recruit behavior to determine what effect, if any, this recruiter selection procedure has on attrition and retention.

Compensation Issues

Compensation plays a major role in both attrition and retention. Many job related discomforts can be compensated for with monetary rewards. The Navy recognizes this fact with its various bonus systems and special payments. An excellent data source and historical background on military compensation can be found in Bartholomew (1976).

Special payments allow differential compensation to be paid for various skills in a system that basically pays an equal amount to people with the same length of service. They cannot be expected to be of much value, however, in a system that in general underpays its personnel. Recent studies have found a steady decline in the ratio of military to civilian pay since 1972. Figure 1 shows this trend, together with the retention rate of mid-grade officers. A detailed analysis of the relationship between officer retention and relative pay can be found in Parker (1979). For example, a 1 percent increase in relative pay and allowances for surface warfare officers with five years of service would result in a 2.7 percent increase in their retention rate.

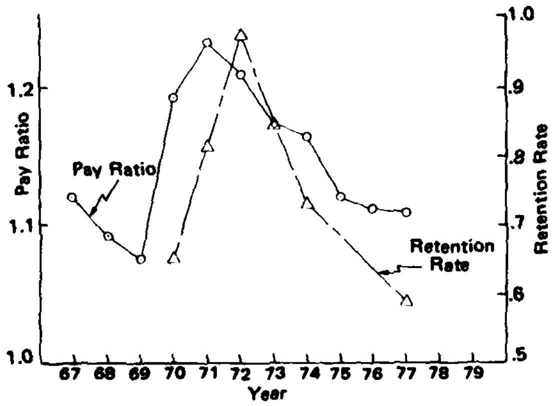

Figure 1. Officer/civilian pay ratio and officer retention rates.

*Military pay is the basic pay and allowances for lieutenants with dependents and more than four years of service. Civilian pay is the median income of white families (published in *Economic Report of the President*, 1979).

**Retention rate defined on page 37 of Parker (1979).

Similar results hold for the enlisted force. Research supported by ONR shows that pay is an important factor in attrition and retention (Note 5); for example, in the boiler technician rating, a 1 percent increase in relative pay and allowances would result in a 6.4 percent increase in retention. The work shows similar results for 37 ratings and highlights the differences among the ratings.

Studies in compensation issues should continue. Currently, the Navy does not have a main focus on economic research, but special studies are undertaken at the Center for Naval Analyses (CNA). NPRDC has limited capability in this area (three economists on a technical staff of approximately 290). The compensation area is so important that it should be supported by special research resources, addressing many questions. For example, how do new entrants view Navy pay and benefits as compared to non-military opportunities? Is retirement, or the prospect of retirement, even considered by junior enlistees in making the decision to remain in the Navy? Can the Navy successfully employ a system of economic incentives differentiated to appeal to different types of people? (For example, high school graduates might be more likely to complete their tours if they knew an attractive GI Bill were available; but nongraduates might be more likely to respond to cash bonuses or technical training incentives.) Manpower costs are now approximately 20 percent of the total Navy budget, excluding retirement costs, which are borne entirely by the Department of Defense (DOD) out of annually appropriated funds. There seems to be ample need and rationale for a substantial research effort into manpower economic problems.

Job Design and Mobility

The area of job design and mobility includes questions about work and why people choose to remain in, or leave, their jobs. Relatively little is known about what motivates job change among labor market entrants—both civilian and military—and how to slow it down. Entrants into the labor market do tend to move frequently, perhaps as a way of trying out jobs and working conditions. If that kind of testing is typical or normal, then the Navy should consider accommodating it; i.e., it should determine the cost and feasibility of offering flexible job assignments during first (and later) tours. Personnel loss might be stemmed if more were known about what young men and women expect of work and why they leave for new jobs.

Most of the approaches to reducing turnover that are described in the literature have been tried in the context of *non-military* employment. The Navy should exploit, on an experimental basis, what has been learned about designing jobs to increase the inherent satisfaction they offer. The Navy should also endeavor to make entry-level jobs challenging and interesting or, conversely, find ways to reduce the boredom that may be a major contributor to dissatisfaction and turnover.

An experimental project (called EPICS, for Enlisted Personnel Individualized Career System) is currently under way in this area (Blanchard & Laabs, 1978; Blanchard & Smillie, in press). Its purpose is to motivate and indoctrinate enlistees through direct assignment aboard ship, rather than to "A" school, following recruit training. The recruits will be given enough job aids to perform their tasks, and thus will experience life afloat *before* the Navy makes large investments in training them. By this means, they will also know whether or not they are suited to Navy life. If they succeed aboard ship and are eligible, they will be sent to "A" school following this initial indoctrination period. This project can be thought of as one step in the direction of career planning for enlisted personnel. Since the EPICS project is just beginning, results are not yet available.

The Navy should continue to support work of this type, along with other research into job satisfaction in general. Questions about the nature of job satisfaction, how to measure it, and the extent to which a lack of it contributes to turnover, need to be answered.

Personnel loss is related to particular ratings: it is very high in some ratings and relatively low in others. For example, a recent analysis of the attrition history of an FY 74 cohort showed the following: (a) attrition at the end of four years for medical specialists was about 19 percent and 47 percent (high school graduates and nongraduates, respectively); (b) four-year attrition for boatswains was only 6 percent and 11 percent, respectively (but note that this rating is entered only after two years of service); (c) among aviation electronic technicians the loss rates were 12 percent and 22 percent. Attrition rates for non-rated men were very high in the 1974 cohort, e.g., SN/SA/SR rates were 74 percent and 85 percent (high school graduates and non-graduates, respectively). Table 3 summarizes these attrition figures for the ratings named. No appropriate interventions to deal with "attrition-by-rating" have been developed. There may be, for example, management options that the Navy can employ on a differential basis for certain ratings. (Selective reenlistment bonuses are one of these options.) Unique work scheduling, leave, and assignment policies for certain ratings should be considered. An example in the civilian sector is that civil air traffic controllers accrue retirement credit at a faster rate than most civil servants because of inherent stresses in their jobs.

Table 3

Four Year Attrition for Selected Ratings: 1974 Cohort, Males; by Education*

	High School Graduate	Non-graduate
Hospital Corpsmen	19%	47%
Boatswains	6%	11%
Aviation Electronics Technicians	12%	22%
Non-rated Seamen	74%	85%

*Note 1.

Personnel Management

More has to be done to determine where people coming from special subsets of the population can serve effectively in the Navy. ("Special subsets" are school dropouts, people who score at the low end of the ASVAB continuum, or people having less-than-average literacy skills. Those who might not be proficient in understanding or speaking English are also included.) The Navy may have to accept more of these marginal personnel than it would prefer, largely because the pool of more attractive recruits is drying up. Special leadership approaches for marginal performers need to be developed, concentrating on improving work habits, building commitment, and making naval service a positive experience. New training approaches to less apt personnel—e.g., self-paced instruction—should be exploited. (Conversely, those recruits who are able to proceed through training at a faster-than-average pace should be encouraged to do so and be rewarded accordingly.) There was a great deal of research on "Project 100,000" men about a decade ago, and its findings should be dusted off for consideration in the 1980s. In essence, people come in a wide range of sizes, shapes, and aptitudes. The Navy must recognize this, particularly in regard to differences in how recruits learn and think, and retain or forget information. Training should deal with individual differences rather than demand conformity to arbitrary and wasteful standards (Sarason, 1977; Jenkins, 1977).

Other personnel management questions concern such innovations as "option-furloughs." This would allow some personnel to leave temporarily, at no cost to their careers, in order to deal with personal problems, explore civilian employment opportunities, etc. (In a sense, this option is already offered to more senior people, i.e., those beyond their first enlistments: some small number of those people leave the Navy and return as "prior service enlistees.")

The recruit trainer—the RTC Company Commander or the Marine DI—should not be neglected. These men and women have unique and demanding roles to play, and their effectiveness directly affects early personnel loss. Research at NPRDC (Manese et al., 1976) has led to the development of test batteries in both the Marine Corps and Navy to help identify effective DIs and Company Commanders. These tests are now being institutionalized. This research marks the first time that the DI has received R&D attention; a great deal more than testing needs to be done to make the DI more effective.

Human Factors Engineering

Little is known about how personnel loss is affected by the design of equipment or work areas (included here is the entire environment in which Navy people live and do their jobs). Is failure to reenlist, for some occupations, an indicator of unsatisfactory working conditions or inadequate tools? Is too much demanded, for example, in the way of diagnostic and maintenance skills for electronic hardware, to the point that people give up? In anticipation of a wider range of abilities or, more realistically, a larger proportion of marginal people, should the Navy design its equipment differently? This is a long-range approach to turnover reduction, but it should be carefully considered. A special case is the long-range plan to incorporate more women into the Navy; because of known sex differences in stamina, strength, and body size, some accommodation has to be made in tools, job aids, and so on.

Societal Trends

The Navy's people are representative of the larger society from which they are recruited. Therefore, changes taking place in American values, beliefs, and behavior should be continually tracked in a systematic way to allow the Navy to anticipate and head off problems. If alcohol or drugs, for example, are being used more often and at earlier ages (as seems to be the case), the Navy should be prepared to deal with such behavior in a positive way.

* * *

This section has not exhausted all that is known (and unknown) about personnel loss, but it is a reasonable compilation of facts and questions that still require answers. The final section deals with optimum attrition and retention rates.

III. Desirable Turnover Levels

Not all turnover is bad. The Navy would not want all first term enlistees to reenlist and remain in service through retirement. Clearly, there are some levels of attrition and retention that produce a desirable force structure vis-a-vis both length of service and pay grade.

The key to determining desirable turnover levels is the force structure required to maintain the Navy. Since little or no hiring into the Navy is done at levels above the recruit, a more closely controlled manpower management system is required than in the private sector. At all times, the Navy must guard against shortages or overages at any level (length-of-service), because the options it can use to correct them are very limited.

Current attrition and retention goals are set primarily in terms of what is needed to maintain a predetermined balance in the system. When turnover rates are far from desirable, such goals prove useful in helping to force the system to react in the right direction. Once turnover rates are at an acceptable level, however, the goals should be determined by policy decisions about the optimal force structure.

Personnel flow models are the tools necessary to determine "optimal" turnover. Use of the term optimal implies that well-defined force-structure objectives have been determined, so that alternate turnover patterns can be considered and the best one chosen. An illustration is depicted in Figure 2.

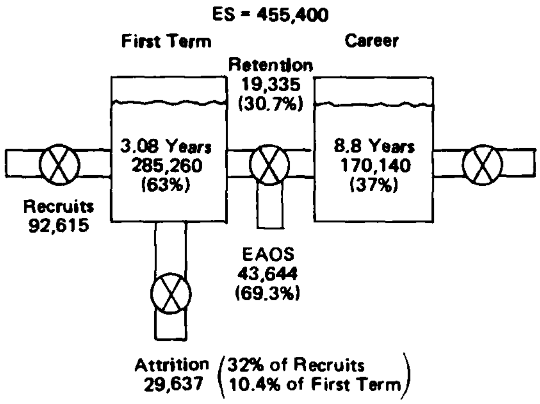

Figure 2. A simple example of a two-stage manpower flow system.

Consider maintaining a total enlisted force size of 455,400 (the current Navy level). The four-year first term attrition is 32 percent and the goal for first term reenlistment is 30.7 percent (of all those reaching the end of their first term of obligated service). As was mentioned in Section I, first term attrition does not occur uniformly during the enlistment period; current experience shows that a first-termer averages 3.08 years of service. Once a person reenlists, an additional 8.8 years can be expected, on average. As shown in the example, these facts indicate an input of 92,615 recruits is needed per year in order to maintain an end-strength of 455,400 (63% first-termers and 37% career force). As first term attrition and retention change, the force structure changes. Is a first term force of 63 percent desirable? Suppose we want only 60 percent of the force to be first-termers. To maintain this level, the attrition and retention rates need to be balanced. For example using the average service time given above, the 60 percent level could be maintained by holding first term attrition to 30 percent and achieving a 31 percent first term reenlistment rate. Other trade-offs could be: 35 percent and 34 percent; or 40 percent and 37 percent.

This simple example considers the total enlisted force as a unit. In reality, each separate skill community (rating) needs to be considered and balanced with possible lateral transfers between communities at various career points. Flow models can be developed to analyze such problems at various levels of aggregation. There is a need for flow models at a reasonable level of aggregation that could be used to help policy makers determine force structures and anticipate the implications of such structures on both turnover and recruitment. Such models would form the basic tools for undertaking long-range planning into force structure, attrition, and retention.

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Issues in the Management of Women in the Navy

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Requirement

The acquisition of new personnel to maintain an adequate force is a continuing problem for the Navy. During FY 80, for example, the Navy must recruit 82,178 nonprior service males to fill its needs (Van Winkle, 1979). It is uncertain, however, whether the Navy Recruiting Command can meet this goal, since it has been able to obtain only 93 percent of similar quotas established for the past 2 years. The Navy is not unique in this respect; all of the military services are experiencing shortfalls, primarily because of the declining number of people entering the labor market and because they must compete with civilian employers for this reduced labor force. Further, this problem is not short-lived. The Rand Corporation has predicted that the number of high quality men (defined as high school graduates in mental categories I, II, and III) that can be recruited by the Navy will drop by 23 percent during the next decade (Fernandez, 1979).

A variety of actions can be taken so that meeting recruiting goals is no longer dependent on a limited supply of nonprior service males. These actions include conscription, increased use of civilians to perform military functions, and recruiting alternative personnel resources. Since conscription requires an act of Congress, it is not an option currently available to the military. Also, even though the numbers of military jobs being performed by civilians has steadily increased, the personnel shortage has not been alleviated (Janowitz & Moskos, 1979). The third proposal, however, offers workable options, including increasing the use of women, prior service individuals, and/or men with less education and ability. While the Navy is exercising all three of these options in FY 80, this discussion is limited to the increased use of women.

Problem

Attempting to substitute women for men in the Navy creates a problem since most Navy personnel policies have evolved based on men and are not necessarily applicable to women. Although few persons would dispute the fact that women as a group differ from men, many assume that men and women having similar characteristics will behave within the military organization in the same manner. This assumption is not necessarily true, not only because of social and biological factors, but also because men and women encounter differential treatment in the Navy. Mental and educational enlistment standards for women are higher than for men, their assignments are restricted by interpretation of the Federal Code, and their advancements are affected by the understandable need to maintain promotional opportunities for individuals whose assignments are not restricted (i.e., men). These are examples of the gender-specific regulations and policies that influence the organizational behavior of women and that have wide-ranging implications for management.

Research and Development Progress and Findings

In 1975, the Navy Personnel Research and Development Center (NAVPERSRANDCEN) began a research program to quantify and describe some of the differences between the sexes that are meaningful to management. Although male and female recruits appear to be similar as to enlistment motivation and experiences with drugs, they differ in their occupational values (Thomas & Durning, 1978, and Olson & Thomas, 1978). This finding led to the conclusion that the work values of the

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majority of women attracted to the Navy in 1975 were not compatible with the jobs that needed to be filled.

Also, the career cycle of Navy women from recruitment to discharge is being investigated to identify unique features that could warrant management attention. Recruitment is a logical starting point, involving questions of supply and female inclination to enlist. Therefore, in December 1977, a nationwide sample of females and males in the prime recruiting age group–between 18 and 25–was queried about their interest in joining each of the services under the then present policy, which involved limiting women to shore assignments, and three alternative options involving greater utilization of women (Borack, 1978). These options were: (I) assigning women to a wider range of jobs but not assigning them to any ships or aircraft or in locations near a front line, (II) assigning women to some support ships and support aircraft, more overseas locations, and near a possible front line, and (III) assigning women and men without regard to gender. Under Option III, men and women would have equal exposure to combat, and equal opportunity for jobs and advancement. Table 1 shows the percentage of women who were interested in enlisting in each of the services under these four conditions.

Table 1

Percentage of Women Interested in Enlisting Under Four Conditions

	Present Policy (1977)	Option		
		I	II	III
Air Force	9.8	13.2	10.8	10.1
Navy	7.9	11.1	8.5	8.4
Army	5.6	7.4	5.6	5.6
Marine Corps	4.7	3.9	3.4	4.7
Overall	14.3	23.9	19.4	19.6

Notes:

1. The overall percentage is less than the sum of the individual percentages because the respondents could express an interest in more than one service.
2. In 1977, the policy was to limit women to shore assignments. Options I, II, and III were: (1) assigning women to a wider range of jobs, but not assigning them to any ships or aircraft or in locations near a front line, (2) assigning women to some support ships and support aircraft, more overseas locations, and near a possible front line, and (3) assigning women and men without regard to gender.

The overall proportion of women who showed a propensity to join the services changed little from Option II (the condition existing in the Navy today, 1980) to Option III, in which women assume the full risk of combat. Of major interest is the fact that the characteristics of women who might enlist in the military were greatly affected by the specific options addressed. Those who were interested in joining under 1977 policies were disproportionately from the South Atlantic states and preferred to work with people rather than machines. As the possibilities for a greater variety of jobs and assignments to combatant ships were introduced, half of this original group lost interest in joining. They were replaced by a new group, who came disproportionately from the Pacific states, were often better educated, and were more likely to work full-time throughout their lives than those interested under 1977 policies.[1] The survey also investigated whether men's propensity to join the military would change as the possibility of working alongside women and serving with them in combat increased. The findings indicated that young men exhibited the greatest interest in the service (30% propensity to enlist) as more jobs were opened to women. Also, assigning men and women without regard for gender, while a less popular opinion (20% propensity), was more attractive than were 1977 conditions (16% propensity).

Job performance, the second step in the career cycle, also has been examined, particularly with respect to so-called "nontraditional" Navy jobs. This term has been defined in several ways. As used here, however, it refers to occupational fields other than the five Department of Defense (DOD) groups to which military women have been traditionally

[1]Women have been recruited in sufficient numbers to meet the increasing goals established during the ensuing 2 years and under conditions described in Option II. Whether the favorable situation is partially due to the changes that have occurred in policies affecting the assignments of women cannot be determined at this time, but these policies do not appear to have had an adverse effect on the female applicant pool.

assigned—communication, supply, data processing, administration/clerical, and medicine/dentistry.[2] A study conducted in 1976-77 compared the attitudes of women in traditional and nontraditional areas toward their work, coworkers and supervisors, and their progress in the Navy (Durning, 1977). Several significant differences were found. While women in nontraditional occupations were less satisfied with the progress they had made in the Navy, their work provided them with greater self-esteem than did that of women in traditional fields. The former group, moreover, felt that negative male attitudes made it difficult for them to do their jobs, that Navy wives resented them, and that they had to prove themselves each time they were assigned to a new work group. Over one-third were dissatisfied with the support they were receiving from their supervisors, versus about one-fifth of the women in traditional jobs. The exit questionnaires of a group of women being discharged before the end of their first enlistment were also dichotomized on the basis of occupational group (Thomas, 1980). Sources of job dissatisfaction for women in nontraditional areas included being assigned more work than could be accomplished and not receiving sufficient training. Also, they reported that they received less support from their supervisors than did the women in the traditional areas.

To most managers, determining whether or not women can do the job is a more pertinent issue than measuring their job satisfaction. Several studies focusing on this question are underway. In one two-phase study, peer evaluations were obtained for women and men in the same work group. Navy occupational ratings included in these work groups were Air Controlman, Aviation Machinist's Mate, Aerographer, Aviation Mechanic, Aviation Electronics Technician, Electronics Technician, Ocean Systems Technician, and Radioman. In this study, raters were considered "biased" if they perceived significant differences between the video-taped performance ascribed to men and women when, in fact, no difference existed. When the ratings of these "biased" raters were included in the comparison of the average evaluations earned by actual Navy men and women, a significant gender difference was noted. When the biased ratings were not included, however, only a small difference resulted, indicating slightly lower performance levels for women. The second phase of this study will focus on tasks that are integral to jobs in which women are not yet assigned. The actual level of performance of men and women on these tasks will be observed and scored (Pope, 1979).

In another project addressing women's ability to perform in new job areas, the Navy Occupational Task Analysis Program was used to identify the most physically demanding tasks in each occupation. A battery of strength and anthropometric measures was developed and is being tested for potential use in the selection of men and women for assignments in which they would have to perform these tasks. While the project is in an early phase, it appears that muscularly demanding Navy jobs mostly involve lifting, carrying, pushing, and pulling heavy objects. As for the development of strength in both sexes, it appears that only small gains and some losses in lifting and pulling capability result from the conditioning that occurs during recruit training. Since the greatest strength differences between men and women are in the upper torso weight lifting and carrying muscles, we can reasonably expect that tasks exceeding the capabilities of a small percentage of men will exceed the capabilities of a much larger percentage of women.

The gender integration of Navy ships is the critical test of the future utility of women as a subset of the total force. The 1978 modification to Section 6015, 10 USC, permitted the Navy to assign women to noncombatant ships. The impact of this change upon unit effectiveness, retention, and readiness is still open to conjecture and scrutiny. With the initial ships, indices of personnel effectiveness are being monitored, and a study of the process of integration is being conducted. The attitudes and psychological sets of the crews prior to integration are being measured, the ability of women to perform shipboard tasks is being observed, and the manner in which each ship pursues integration is being evaluated.

Beyond this issue of whether women are willing and able to fill the personnel resource void are questions of cost and effectiveness. A DOD sponsored study of the cost implications of increasing the number of women in the military concluded that

[2] In 1974, NAVOP Z-116 opened certain professions to women officers, and called for the admission of enlisted women to *all* Navy jobs. In reality, those jobs that are primarily performed aboard ship have remained closed to women.

costs for recruiting and retiring are less for women than men, and that costs for sustenance and training were about equal for the sexes (Adams & Welsh, 1978). Costs included in the analysis were retirement pay and benefits used by the retiree and his/her family. Despite the longer lifespan of women, they tend to retire at an earlier age than men, when their average rank or pay grade is lower, and, as a consequence, so is their retirement pay. Also, military women frequently remain single and/or childless, resulting in lower costs for dependents during both active duty and retirement years. While the research at NAVPERSRANDCEN has not addressed costs in terms of actual expenditures, men and women have been compared on two factors that affect costs attrition and lost time.

Data concerning the attrition rate of women are conflicting and time-dependent. Historically, the separation rate of women has been higher than, even double, that of men. A partial explanation for this situation was the lenient practice of discharging a woman who was unhappy in the service as well as the regulation that required the release of a woman who became pregnant. In 1975, this regulation was changed, creating a noticeable impact on women's attrition rate. For example, DOD reported that first-year separations of women enlisting in FY 76 were slightly below those of men (Use of Women, 1977). In the longitudinal investigation underway at NAVPERSRANDCEN, researchers are tracking 1,011 males and 979 females who enlisted in the summer of 1975. After 1 year, 16 percent of the women versus 14 percent of the men had left the Navy; at the end of 2 years, 25 percent of both groups had left; and at the end of 3½ years, the attrition rate was 39 percent for both women and men (Thomas, 1980). Navy personnel reports comparing male and female first-term enlistees usually conclude that the attrition rate of women is still higher than that of men. Such results do not necessarily contradict those found at NAVPERSRANDCEN. They differ because a different method is being used to identify the women and men being compared.[3]

[3]Comparisons between male high school graduates entering the Navy and all women enlistees also yield higher attrition rates for women, but such data do not reflect *actual* input to the Navy.

The factors contributing to the attrition of women and men appear to be very different. One clue lies in the finding that the women in the research sample who left the Navy before their enlistment contract expired had higher entrance test scores than those who remained, whereas the reverse was true for men. Another clue is the type of discharge women receive. Among the samples discussed above, honorable discharges were awarded to 83 percent of the women and 30 percent of the men who left during the first 2 years. The most common reason for separating the women was pregnancy, as shown in Table 2 (Olson & Stumpf, 1978). When the women were asked what changes would make them want to remain in the Navy, their most frequent answers revolved around increasing Navy support for family life. These women cited the need for child care facilities, longer maternity leave (or an interrupted enlistment), assigning husbands and wives together, and eliminating or reducing overnight duty.

Table 2
Reasons for Discharging Men and Women in the Sample During First 24 Months

Reason for Discharge	Percentage Female (N = 258)	Male (N = 264)
Pregnancy	41	0
Unsuitability	35	36
Convenience of Government or Enlisted in Error	8	8
Misconduct or Deserted	4	17
Physical Disability or Died	3	7
Released from Active Duty	2	10
Good of Service or Fraudulent Entry	1	4
Other Reasons	1	5
Unknown	5	13

Note: From Olson, M.S., & Stumpf, S.S. *Pregnancy in the Navy: Impact on absenteeism, attrition, and work group morale* (NPRDC Tech. Rep. 78-35). September 1978 (Table 5).

The question of who loses more duty time, men or women, was investigated with the research samples that had enlisted in 1975. Pay records were obtained for all people in the sample who were still on active duty on 1 July 1976 (i.e., 821 women and 872 men), and medical tapes were used to obtain information on the number of hospitalization days during calendar year 1976. Table 3, which presents the data obtained from these files, shows that the number of incidents of lost time for each reason and the number of days lost per 100 personnel were quite different for women and men (Olson & Stumpf, 1978). Women tended to be absent for medical reasons, and men for disciplinary reasons. (Sixty percent of the men were on sea duty on the first day of the lost time period, versus 40 percent on shore duty. There was no difference in the amount of lost time incurred by men on sea and shore duty.) Combining all categories resulted in an annual per capita loss of 4.2 days for women and 7.0 days for men, as recorded on pay records and medical tapes. Since personnel are not paid while on disciplinary status, the men were paid for only 1.8 of these days, compared to 3.9 for women.

Table 3

Recorded Absences During 1976 of Women and Men in the Cohort Samples

Reason	Number of Incidents Per 100		Number of Days Lost Per 100	
	Women	Men	Women	Men
Convalescence[a]	6	1	108	25
Awaiting Physical Examination Board	b	1	11	19
Hospitalization[a]	28	11	277	142
Confinement	0	2	0	80
Unauthorized Absence	2	15	26	437
Annual Total per 100	36	30	422	703

Note:

1. From Olson, M.S., & Stumpf, S.S. *Pregnancy in the Navy: Impact on absenteeism, attrition, and work group morale* (NPRDC Tech. Rep. 78-35), September 1978 (Table 2).

[a]Includes absences due to pregnancy and to childbirth.

[b]Less than 1 per 100.

The conflict between pursuing a Navy career and family responsibilities is receiving more attention since the recent surge in the numbers of women in the military. Now women represent 5 percent of the force, and two-thirds of those who are married are married to military men. As a result, problems have developed for both active duty couples and for the Navy when planning reassignments. Results from a 1979 representative survey of women and men with dependents demonstrated that women feel more conflict between having children and pursuing their careers than do men (Nieva, Yedlin, & Rieck, 1979). Since most men who have children living with them have a spouse to care for those children, this finding is not surprising. Because of irregular working hours, overseas assignments, and similar eventualities, arranging for consistent, quality child care becomes a nearly overwhelming responsibility for Navy mothers. Nevertheless, male and female parents reported taking similar amounts of time off for child care. The survey also investigated the problems associated with having an employed spouse, a situation that is true of almost all married women. Women reported more difficulty than men did in arranging work for themselves and their spouses in the same locality.

The attitudes of military wives toward the increased use of women have also been measured, along with their resistance to the gender integration of ships. Less than 10 percent of the sample of 463 aviation wives surveyed in 1976 and 1977 felt very negative about the possibility that women would be assigned to ships on which their husbands were serving, although an additional 16 percent of officers' wives and 34 percent of enlisted men's wives didn't think they would like the situation.[4] Of particular significance was the finding that wives were no more resistant to the prospect of their husbands serving with women at sea than they were to the prospect of their standing after-hours watch with women ashore.

Policy Impact[5]

The problems that have been discussed in the preceding pages are personnel issues that have become research worthy because the numbers of women in the services are increasing and gender differences do

[4]While no research data exist on the attitudes of husbands of Navy women, conversations between the author and women being assigned to ships suggest that male spouses don't like having their wives on ships with men.

[5]Statements in this section are based on the author's judgment and experience in interpreting research findings.

exist. The implications of these research efforts are many, calling for innovative thinking, persuasion, and, perhaps, courage when attempting to implement policies that may challenge deeply ingrained beliefs. In other words, controversial steps may have to be taken if we are to realize the true potential of female Navy members. For example, reducing the attrition rate of women will require a distinctly different approach than the one traditionally used for males. In this case, the goal is not to select applicants of higher aptitude or without predelinquent tendencies; rather, it is to develop new policies to deal with the major cause of female separation--pregnancy. Because it appears that women do not present as many behavior problems leading to disciplinary actions as do their male counterparts, much may be gained by encouraging them to remain in the Navy. For example, 24-hour child care facilities could be established. Indeed, past experiences indicate that the operation of such facilities would be cost effective. For example during World War II, two Kaiser shipyards in Portland, Oregon, found that the benefits gained by providing free, on-site, around-the-clock child care for their numerous women employees outweighed the disadvantages (Canon, 1978). Since a child care program subsidized by the Navy might also be attractive to active duty men who have working wives, its implementation could also reduce male attrition.

The attrition of women and some groups of men could also be reduced by changing assignment policies. First and foremost, a system that would assure the joint transfer of active duty couples should be considered. This system would apply to over 60 percent of all married military women and to 4 percent of all married military men. Women often leave the Navy because they stand a better chance of living with their husbands as civilian wives than as Navy women. Second, the policy prohibiting Navy couples from serving aboard the same ship, which was formulated before such a possibility ever existed, should be reevaluated. Third, a means should be found to permit a husband and wife to have the same sea/shore rotation schedule. Few couples would consider tolerable a life style that has one spouse at sea and the other on shore for 3 years, followed by a reversal of these assignments. One of the pair may drop out and contribute to the already difficult retention problem.

As noted earlier, the creation of policies to accommodate the basic needs of couples to be in the same geographic area and of parents to provide for the care of their children will call for firm actions, particularly since many individuals do not view such actions as either relevant concerns of the Navy or cost effective. These recommended policies would not affect only women, because the sheer numbers of men with similar family circumstances are invariably larger (but may be proportionately smaller) than the numbers of females.

A comprehensive program that would result in the recruitment of the kind of women the Navy needs should be instituted. While no shortfall of female enlistees exists, self-selection as a method of recruitment lacks focus and perpetuates the status quo. Although today's Navy requires women who will participate more fully in the Navy's mission than at any time in the past, the young women who are joining the Navy are not aware of this fact (Thomas & Durning, 1978). Therefore, instead of just including a women in recruiting pictures, materials specifically oriented toward women who want to work in other than traditional jobs need to be developed. These materials should be adopted for advertisement in magazines read by contemporary young women. An active public relations campaign to further communicate the message should accompany this effort.

The problem resulting from the lack of supervisory support perceived by women in nontraditional jobs should be recognized and addressed. The results of surveys discussed in the preceding pages are not isolated events, since comparisons made between the responses of thousands of men and women to the Navy's Human Resource Management Survey support the findings (Durning, in review). On all five indices of Supervisory Leadership, Navy men at pay grades E-4 and above were significantly more positive than women, whereas the reverse was obtained at the lower pay grades. Thus, although women in the lowest pay grades, E-1 through E-3, view their supervisors as more supportive than do men, this relationship steadily deteriorates as women advance through the petty officer ranks. Additional research is needed to determine the basis for this trend. In the meantime, leadership courses should be revised in an attempt to counteract the trend.

The preliminary findings from the project addressing the physical strength of women raise several policy issues. First, training to increase the lifting and carrying capabilities of women should be investigated. Second, we need to know how much conditioning occurs on the job from actual performance of the demanding tasks.

The design of all future platforms, weapon systems, and equipment should consider female anthropometric and strength norms. If women are to function safely and effectively in a work area or to use certain equipment, human engineering technology should be applied as the system is being designed. Success in selecting women who are strong enough and big enough to operate existing systems is constrained by the physical characteristics of the adult female population. Thus, the ultimate goal of research in this area should be the development of systems in which men *and* a reasonable proportion of women could function interchangeably.

The price of fully implementing these recommendations may be prohibitive; thus pilot studies should be undertaken to determine whether it is cost effective to proceed on a Navy-wide basis. Since the shortage of nonprior service males will exist for many years, the use of women as a personnel resource should be fully explored.

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Visual Simulation for the Navy

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Introduction

In flight simulators, visual systems provide the view of the outside world seen by the pilot. In the 20 years or so that such visual systems have existed, development has been active on several fronts and whole simulation technologies have waxed and waned. The proven economic and safety advantages of using simulation to effectively train aircrews to operate sophisticated aircraft are strongly accepted by the major airlines. In recent years these same objectives have increasingly occupied the attention of military aircraft operators through expanded use of available technology. This attention, in turn, has driven the development of ever more sophisticated training simulators. While improvements in computers and aircraft data are important for advanced simulation, these items essentially can be bought with time and dollars as demand requires. It is the visual system that requires the greatest degree of innovation to meet the demanding military visual flying task needs in simulators with affordable equipment.

The Navy has primarily used visual simulation for aircraft, although most of the submarine attack training centers have periscope simulators giving a view of ships at sea, and improvements to these simulators are planned. As far as the surface Navy is concerned, there is no ship-handling trainer/simulator with a significant visual system in service at present, although a few civilian systems exist. Increased use of visual simulation for the surface and subsurface Navy can be predicted as the technology develops and the effectiveness of simulation is increasingly demonstrated.

Background

The role of simulation in aircrew training has expanded from the basic requirement for uncomplicated hardware for instrument and procedures training to the current demands for full-mission simulation of entire weapon systems. The "push" for full mission simulation has been exerted from all sectors of aviation. Training requirements of civil aviation and the manned space programs provided the early impetus for specific visual displays. Advanced direct view optical displays and the first daytime computer image generation (CIG) system were developed to fulfill the NASA training requirements for the Apollo space program in the early 1960s. Soon thereafter, the major civil airline companies had simulators with visual displays of sufficient quality that they could substitute for the major portion of their in-flight training requirements. Current visual technology to meet airline requirements is considered by the industry to be of sufficient quality to recommend 100 percent substitution of simulation for in-flight training (Total simulation crew training pushed, 1979).

The gains made by the simulation research and development (R&D) activities in visual technology fulfill certain specific requirements (e.g., Apollo programs, the airlines, and some military training) but do not meet all of the existing and emerging military training requirements. Current visual displays do have the capability to provide effective simulation for the tasks of night carrier/field landing, day field landing, some in-flight refueling, and limited air-to-air maneuvering. These capabilities are at the leading edge of the state of the art, and are limited in scope compared to the military training need.

Present Status—Technology

Every visual system can be considered to consist of an image generator and a display, and the currently available technology can be briefly reviewed from this viewpoint.

The display has one or more display devices, either cathode ray tubes (CRT) or television projectors that project images onto a screen. A CRT, if viewed directly and set near enough to the pilot's eyes to subtend a reasonably large viewing angle or field of view, would present its image in a very unrealistic manner as it would intrude into the cockpit and the pilot would have to focus his eyes at a very short distance. All CRT displays for simulation use an optical system to present to the pilot a virtual image of the CRT face, the image appearing to be located in the far distance as in the real world.

One technique for generating the virtual image is to mount a large plastic lens in front of the CRT ("refractive optics"), but by far the most popular system (in view of its improved performance) is one in which the pilot looks horizontally into a concave mirror through a semi-reflective flat beam splitter set at 45° to the vertical, the CRT being mounted face downwards. The light leaving the CRT is reflected off the beam splitter, is then reflected by the concave mirror, and finally passes through the beam splitter into the pilot's eyes. This system may be referred to as a "single channel, folded, on-axis vertical image CRT display." Each CRT/beam splitter/concave mirror "window" or channel is mounted just outside the cockpit windscreen to give a field of view of about 48° horizontally and 30° vertically. A single display channel may be used to present a pilot with a straight-ahead view, or multiple channels may be used to cover a wider field of view and serve two pilots. A continuous field of view without gaps is not readily attainable with this type of display; parts of the windscreen through which the display windows are not visible appear dark.

Two types of CRT are used for the display: the calligraphic type and the raster type. In a calligraphic CRT, the beam forming the light spot is deflected in accordance with the image to be displayed—a line of runway lights is "drawn" by moving the spot along the line and turning up the brightness to show a bright dot for each runway light. A system of this type can readily reproduce bright spots representing lights, and can reproduce various areas on the ground such as a runway, touchdown markings, etc. But it has a limited capability to reproduce real-world objects, and is limited to night or dusk simulated conditions. The range of colors does not include blue.

Most CIG systems are of the calligraphic type and can show several thousand light points to adequately represent a night scene with all the lighting patterns used for field, carrier, and helicopter landing, together with the surrounding cultural lighting.

For reproducing day scenes, a CRT capable of displaying a raster (i.e., scanned image) over the whole tube face is required so that the appropriate brightness and full range of colors can be used, as seen on a television receiver. The day scene is built up of points that are joined to make edges; several edges are joined to make a polygon (which is assigned to correct brightness and color); and, where necessary, polygons are assembled to make solid objects such as buildings. Scene complexity is currently limited to about 8,000 edges. This degree of scene complexity is adequate for many purposes, but is insufficient where close approach to terrain is involved and the simulation task is highly terrain-dependent.

Calligraphic systems are highly cost effective within their limitations, but if a full day scene is required the greater expense of the raster system and CRT is necessary. A recent development, at an intermediate cost, has a raster-type CRT giving full color and brightness sufficient for day simulation, with calligraphic deflection.

An image generator that predates CIG is the modelboard/television camera system that was used extensively by the airlines before its replacement by CIG. The display can be very similar to the CIG display with the 48° by 30° field of view, or projector arrangements can be used. Wider fields of view are difficult to achieve if good resolution and other desirable features are to be retained.

For air combat, a wide field of view is essential, but low detail is acceptable except for the images of target aircraft. The usual arrangement is to have the pilot seated at the center of a spherical screen or dome and to project a low-detail earth/sky scene onto the dome using a shadowgraph projector, with high-detail aircraft target images added by servo-controlled target projectors.

Other display arrangements are available, such as the multiple "Pancake Window" display used by the Air Force on their Advanced Simulator for Pilot Training (ASPT) at Williams Air Force Base. The Pancake Window may be described as a "single-channel, in-line, on-axis virtual image CRT display," by comparison with the "single-channel, folded, on-axis virtual image CRT display" already referred to. The distant image of the scene on the CRT face is again obtained using a concave mirror (this time semi-reflecting) and a beam splitter, but in the Pancake Window they, and the CRT face, are all normal to the line of sight. Light polarizing arrangements are used to avoid additional, spurious images (such as the direct view through to the CRT face), but at the expense of considerable loss of light and with the limitation that only a black and white CRT can be used, rather than a color one.

Although Pancake Windows have certain advantages—they can, for example, be readily butted to give a wide field of view—and they are being developed further by the Air Force, the Navy has not favored them for acquisition, largely in view of their high cost.

Present Status—Visual Systems in Use

Visual displays are now generally accepted by the military training community for aircraft training in a "part task" role. The narrow field of view television camera/modelboard technique, for example, is used for takeoff and landing training in the P-3C and KC-130 trainers.

However, although currently the modelboard can give more realistic terrain detail than can CIG, the maintenance and operating costs are higher. The current trend is away from camera/modelboard image generators and in favor of the commercially available night CIG visuals for this task, as they can support other tasks such as antisubmarine warfare (ASW) tactics training in the S-2A and Light Airborne Multi-Purpose System (LAMPS) MK I (SH-2F) helicopter trainers.

A new part task trainer, the Air Combat Maneuvering Simulator (ACMS) (Figure 1) has been developed specifically for the Navy, and is now installed at Naval Air Station (NAS) Oceana. It is the first wide-angle system to be used as a trainer.

The ACMS has two 40-foot-diameter dome screens with background, aircraft target, and missile projectors. Two aircraft images can be separately projected, each representing either friend or foe. Each dome has a cockpit at its center, and the two trainee stations can be operated independently or in an

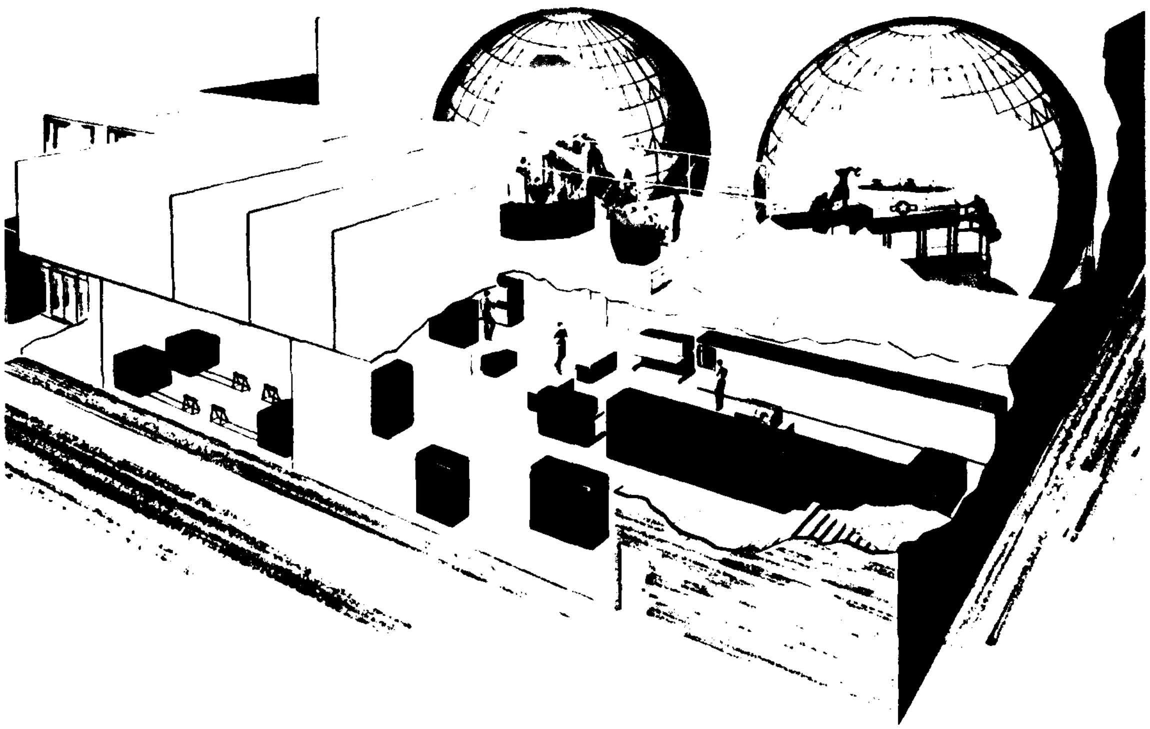

Figure 1. Air Combat Maneuvering Simulator.

integrated mode. Instructor or computer control of the target aircraft is provided. At present, the ACMS simulates the performance of the F-4, F-18, and two threat fighters and armaments.

The part task training philosophy is being continued in trainers for new Navy aircraft such as the F-18 and LAMPS MK III (SH-2F). The F-18 trainers comprise a training suite with commercial dusk-night CIG visuals to be used on the Operation Flight Trainer (OFT) and a specially developed wide-angle display for the Weapons Tactics Trainer (WTT). For the LAMPS MK III training suite, the visual system needs are reversed, in that commercial night displays meet the ASW weapon and tactics trainer requirements while the OFT may need a special wide-angle display for training landing on small-deck ships at sea, especially in adverse weather conditions. This illustrates the importance of the configuration analysis balance required for each military aircraft, its missions, training tasks, and training equipment selection, as compared with the single takeoff, landing, and taxi task supported by off-the-shelf simulator visual displays in commercial pilot training.

This covers only a portion of the military full mission spectrum visual requirements. A major area of concern is in the air-to-ground and low-level flight regime where no effective visual display has been placed in operation. Also, a role for visual systems on simulators for Navy Basic Undergraduate Pilot Training does not currently exist. This will be closely examined as part of the acquisition of the new VTX/TS next generation training system. Visual system cost is a much greater restriction on applying visuals to simulators for lower-cost training aircraft than it is for fleet aircraft, since there the ratio of simulation cost to the cost of using the actual aircraft is higher.

Table 1 lists Navy visual systems and their associated simulators that are either in service or will go into service in FY 80 or FY 81.

Effectiveness of Visual Simulation

Aircraft Visual Systems

The effectiveness of training using visual simulation is a measure of the proficiency attained by the trainee in flying the aircraft. The cost effectiveness is a measure of the cost (compared with training carried out in the vehicle itself) for a given standard of proficiency achieved.

The major airlines have long been knowledgeable in this area and, as commercial enterprises, have concentrated on cost effectiveness, using Federal Aviation Administration (FAA) credits to specify the training standard (Moran, 1971).

Taking the cost of ownership of a simulator and visual system (i.e., acquisition cost plus cost of maintenance over the expected life), an hourly cost for using the system can be computed. This is then compared with the total cost per hour of running the aircraft itself for training. The aircraft-to-simulator cost ratio is typically between 20:1 and 5:1. The need for applying cost effectiveness criteria to Navy aircraft simulation is apparent.

Studies have been carried out on the P-3C landing and takeoff trainers, in which the aircraft type approximates to the well-studied airline transport and the visual system is of the well-known camera/modelboard type. Smode (1979) demonstrates, for fleet replacement pilot training, a reduction of in-flight hours from 15.1 to 8.2. Orlansky and String (1979) have analyzed the corresponding cost effectiveness to show an estimated saving of $2.5 million per year and, on this basis, amortization of the new simulator within two years.

There is a lack of similar data for other Navy simulators with visual systems. An initial investigation has been made into the methodology necessary for evaluating the training effectiveness of the Air Combat Maneuvering Simulator at NAS Oceana by measuring pilot performance in the aircraft and in the simulator. More work is necessary and would have to be extended further to cover cost effectiveness.

What is really needed is a major effort to quantify the benefits of visual simulation: cost, safety, fuel saving, conserving vehicle life, reducing the need for real-world training space, and performing training impossible to carry out in the vehicle itself.

In the case of aircraft, the mission profile for each type should be studied and maneuvers that cannot be effectively trained with currently available technology should be considered in the light of new technology emerging from the research

Table 1
Navy Visual Systems Used for Training, and Associated Simulators

Weapon System	Simulator Type*	Simulator No.	Visual System No.	Image Generator	Field of View**	Display	Simulated Maneuvers
TA-4J	OFT	9	2	CIG day/night 1000 edges, color raster system.	210° H 60° V	Mosaic of 3 rear-projection flat screens, 3 TV projectors	Carrier & Field Landing Familiarization/cross country. Air-ground weapons
A-4M	OFT WST	P	P	P	P	P	Air/Ground
A-6E	OFT	2	2	Calligraphic CIG Night/dusk	48° H 36° V	4-window, 3 channel folded on axis virtual image CRT	Landing, cross country
	NCLT	2	2	Calligraphic CIG Night/dusk	48° H 36° V	2 window, 1 channel folded on axis virtual image CRT	Night and dusk carrier landing
EA-6B	WST	1	1	Calligraphic CIG Night/dusk	120° H 48° V	3 window, 2 channel, folded on axis virtual image CRT display	Night and dusk landing, field and carrier tactical area
A-7E	NCLT	2	2	Calligraphic CIG night	42° H 32° V	1 window on axis virtual image CRT display (refractive optics)	Night carrier landing
	WST	2	2	Video disc stored photographic data, digital scene interpolation	Various, to meet training mission within forward ¼ sphere and down 30°	Mosaic of 6 rear-projection screens with 4 TV projectors	Air/Ground Weapons cross country field landing
	LSO Trainer	2	2	Calligraphic CIG night	72° H 36° V	2 edge matched, virtual image displays, refractive optics	A-7 Aircraft Approaching Carrier, LSO controlled
KC-130	OFT	1	1	TV camera/model-board	48° H 36° V	Off-axis concave mirror and projector "Duo-view)"	Takeoff and landing
F-4J	WST	4	2	CIG, night Calligraphic	144° H 32° V	3 window folded on-axis virtual image CRT display	Field and carrier takeoff and landing
F-14A	OFT	4	2	CIG, night/dusk Calligraphic	46° H 32° V	1 window folded on-axis virtual image CRT display	Field takeoff and landing
	WST	2	2	TV camera aircraft and carrier models, "shadowgraph" background	350° H 150° V	Spherical dome screen, 5 computer-aimed projectors, one with zoom plus 2 missile projectors.	Carrier takeoff and landing Air/air combat
F-18	OFT	1	1	Calligraphic CIG dusk/night	48° H 36° V	3 window 3 channel folded on axis virtual image CRT	Field and carrier landing, cross country, limited air-surface weapon delivery.
	WTT	2	2	Aircraft models & background, CIG color raster system	360° H 150° V	Spherical dome screen, 4 computer-aimed TV projectors	Air/Air
F-4 F-14 F-18	ACMS	1	1	TV camera aircraft model, "shadowgraph" background	350° H 150° V	Spherical dome screen, 4 computer-aimed TV projectors & 1 missile projector	Air/Air
SH-2F	WST	2	2	CIG, night Calligraphic	144° H 32° V	3-window folded, on-axis virtual image CRT display (segmented)	Field, ship and carrier takeoff and landing and ASW tactical operations
CH-46	OFT	3	2	CIG, day/night 6500 edges, color raster system	175° H 50° V + chin window	6-window folded, on-axis virtual image CRT display (segmented)	Field, ship (LPH, LPD) and confined area takeoff and landing
CH-53	OFT	3	P	P	P	P	Field, ship and confined area takeoff and landing
P-3C	OFT	5	4	TV camera/model-board	48° H 36° V	Off axis concave mirror and projector ("Duo-view")	Field takoff and landing
			1	CIG, night/dusk Calligraphic	48° H 36° V	1 window folded on-axis virtual image CRT display	Field takeoff and landing
S-3A	WST	5	5	CIG, night Calligraphic	144° H 32° V	3 window two channel folded on axis virtual image CRT display (segmented)	Field and carrier takeoff and landing
TAV-8A	OFT	1	1	P (CIG day/dusk color raster system)	P (200° H) (65° V)	P (virtual image CRT)	Field, ship (LPH, LPD) and confined area takeoff and landing
AV-8B	WST	3	3	P	P	P	Air to ground, visual acquisition of targets

*OFT – Operation Flight Trainer
WST – Weapon System Trainer
NCLT – Night Carrier Landing Trainer
ACMS – Air Combat Maneuvering Simulator
WTT – Weapons Tactics Trainer

**H – Horizontal field of view (degrees)
V – Vertical field of view (degrees)
P – Planning in Progress

laboratory. The decision to build advanced simulators to extend the range of training simulation depends on many factors, among which cost effectiveness is preeminent.

An important part of such studies is the determination of how real the simulation must be for effective training. In general, as the simulated scene is made to approach realism, the cost increases rapidly; even if full realism were technically feasible, the cost would be quite unacceptable. A cost-effective visual simulator will provide the visual cues needed for training the missions for which it is designed. An essential part of the writing of a specification for a visual simulator is the definition of these cues. In effect, visual fidelity must find its place in the training system, recognizing that the actual flight hours in the aircraft are a part of the training sequence.

Submarine and Ship Visual Systems

Turning now from aircraft to submarines, most of the existing attack training centers have periscope view simulators that use television techniques for viewing ship models. Following the Advanced Visual/Near Visual Submarine Periscope/Electro-Optic Infrared Sensor Simulator (AVEOSS) program, all the centers are to be fitted with CIG ship image generation systems, with procurement commencing in FY 84.

For harbor navigation, a terrain view is necessary and CIG systems are planned for acquisition commencing in FY 80. The images will, however, be somewhat stylized and will not allow close approach to a pier or other object.

For the surface Navy, visual simulation is not yet available. A number of studies (Cordell, Nutter, and Heidt, 1979) on ship handling requirements have been produced and further studies are about to commence, including reference to new visual system techniques in development. For navigation near coastlines, the high detail imagery requirements are similar to those for submarines. In addition, a high-resolution, wide-field-of-view display is required without visible joins in the image for the view from the bridge.

Visual R&D Technology

Visual R&D efforts must address the development of cost- and training-effective visual hardware and utilization techniques that will provide effective simulation of air combat, air-to-ground attack, fixed-wing and vertical takeoff or land/short takeoff or land (VTOL/STOL) takeoff and landing, low-level flight, and formation flight in full mission training, or as a minimum, in part task trainers. Ultimately, the aim is to simulate the visual scenes necessary to support an F-18 or LAMPS MK III combat sortie in the simulator from engine start to stop. Of specific note is the fact that visual technology gains made for aircrew training are also of major importance to surface and subsurface operator simulations. High detail imagery generation and display are common requirements, and a wide field of view is required for both aircraft and ship.

Current visual research and development work is aimed at closing these technology gaps. The areas in which improvements are being made are:

High Resolution

For air-to-ground weapon delivery and low altitude flight, a highly resolved view of the terrain and ground targets is necessary for useful training. Resolution should be no worse than that encountered under practical flying conditions, at least in the pilot's viewing direction.

Field of View

Air combat maneuvering and weapon delivery require a wide-angle field of view. VTOL operations (Woomer and Carico, 1977) require a large down-viewing angle (50° or more) coupled to a wide horizontal field of view. Displays must be developed for single pilots and tandem or side-by-side seated aircrews.

Scene Detail

To fly effectively at low level and perform VTOL takeoff and landing, current knowledge indicates that a highly detailed scene is necessary. This includes realistic contoured terrain and trees seen from below treetop level. The same detail is required to support VTOL training from decks of ships.

Dynamic Scene Content

Weapon delivery requires the highly dynamic display of missile firing, weapon bursts, and enemy weapon threats and explosions. Operation in the ocean environment can demand the visualization of wave/sea action.

Gaming Area

Gaming area requirements run the gamut from carrier/field landing pattern limits to terrain area suitable for full-mission low-level sorties. This requires visual data bases that vary from a small modelboard to a CIG data base encompassing thousands of square miles of terrain.

Current efforts in visual simulation research and developments are focused upon efforts to respond to the technology thrusts. High resolution and wide field of view are two visual characteristics that must be considered together, in that for a given amount of visual data there is a tradeoff between them in designing a suitable display.

As has already been indicated, currently available wide field-of-view displays are of two main generic types: those in which images are projected onto the inside of a spherical screen and those which use a number of cathode ray tubes, sharing the total displayed field of view between them. Systems are not yet available where highly detailed, high-resolution images can be made to cover the surface of the screen surrounding the pilot, although high resolution images can be shown over small areas of the screen as is required for air-to-air combat. The multiple CRT displays also have limitations, particularly with the visibility of the joins between the individual image segments that make up the total field of view.

Displays that use a scanned laser beam covering a substantial part of the inside of a spherical screen to give a high-resolution, high-detail display with a wide field of view have been extensively studied (Driskell & Spooner, 1976 and Oharek, 1977) and are the subject of continuing developments. Multiple television projectors are currently in use for this purpose.

To supply the large amount of visual data required, in real time, for such a display, two main approaches are being developed. One approach is to use a modelboard carrying a high-detailed contoured model of the terrain and scan it with a laser beam to generate color TV type signals that are fed to the display. The other approach is to use an advanced form of CIG capable of the high detail that can be built into a physical model.

The modelboard/laser approach has been shown to be feasible, but CIG systems currently available do not have sufficient detail for adequate training in missions calling for a close approach to terrain. New architectures are being explored with a view to making the required detail available in the future. The CIG approach is preferable to the modelboard approach, subject to equal detail capability, in that it can be used for almost unlimited gaming areas, occupies much less building space than a physical model, and can be readily changed.

However, apart from the fact that CIG is unlikely to reach such a state of development for a number of years, the time taken--and hence the cost--to create the necessary data base is becoming prohibitive. A typical airport data base, largely two-dimensional, containing 4,000 edges and representing an area of 25 square miles would not be unreasonably expensive at $35,000 to $40,000. However, a large data base containing in the order of one million edges could cost around $0.5 million.

The cost is in the skilled labor required; there is clearly a need for automating the process. Work has been in progress over the past two years on the problem of automatic or semiautomatic data base creation--the use of real-world data as made available, for example, by the Defense Mapping Agency, for creating the data base with a minimum of human intervention. Very substantial reduction in the man-hours needed to generate complex data bases can be expected in the future.

Another approach to the problems of displaying a scene having both high resolution and wide field of view (and hence a very high requirement for visual data in real time) is to display a limited field of view only, but to move the displayed field of view with the pilot's head so that he can look in any direction but always have the appropriate imagery displayed to him. This type of display has a beneficial effect on the image generation requirements. Although the total size of the visual data base cannot be reduced, the amount of visual data that has to be generated in real time is much less than is required for displays that produce an image that continuously covers a very wide field of view.

This principle is well known, and it has received increasing emphasis as the demands for more visual data have increased. Exploratory developments are in progress on systems for displaying a 90° instantaneous field of view (IFOV) to the pilot, moving with his head direction, with imagery derived from a CIG system (see Figure 2). The use of a scanned laser beam to generate the image is favored in view of the high resolution and relatively high light intensity that can be achieved. The projection lens, mounted on the pilot's head, is coupled to the laser/optical system by a flexible optical link. The successful implementation of such a system would lead to improved performance and reduced equipment cost as compared with existing wide field-of-view systems that generate detailed imagery.

Beyond coupling the display to the pilot's head direction, a further development would be to measure the pilot's eye direction continuously and to generate and display within the displayed field of view an area of interest (AOI) having higher scene detail than in the rest of the field of view. The AOI would move so as to continuously track the pilot's eye fixation

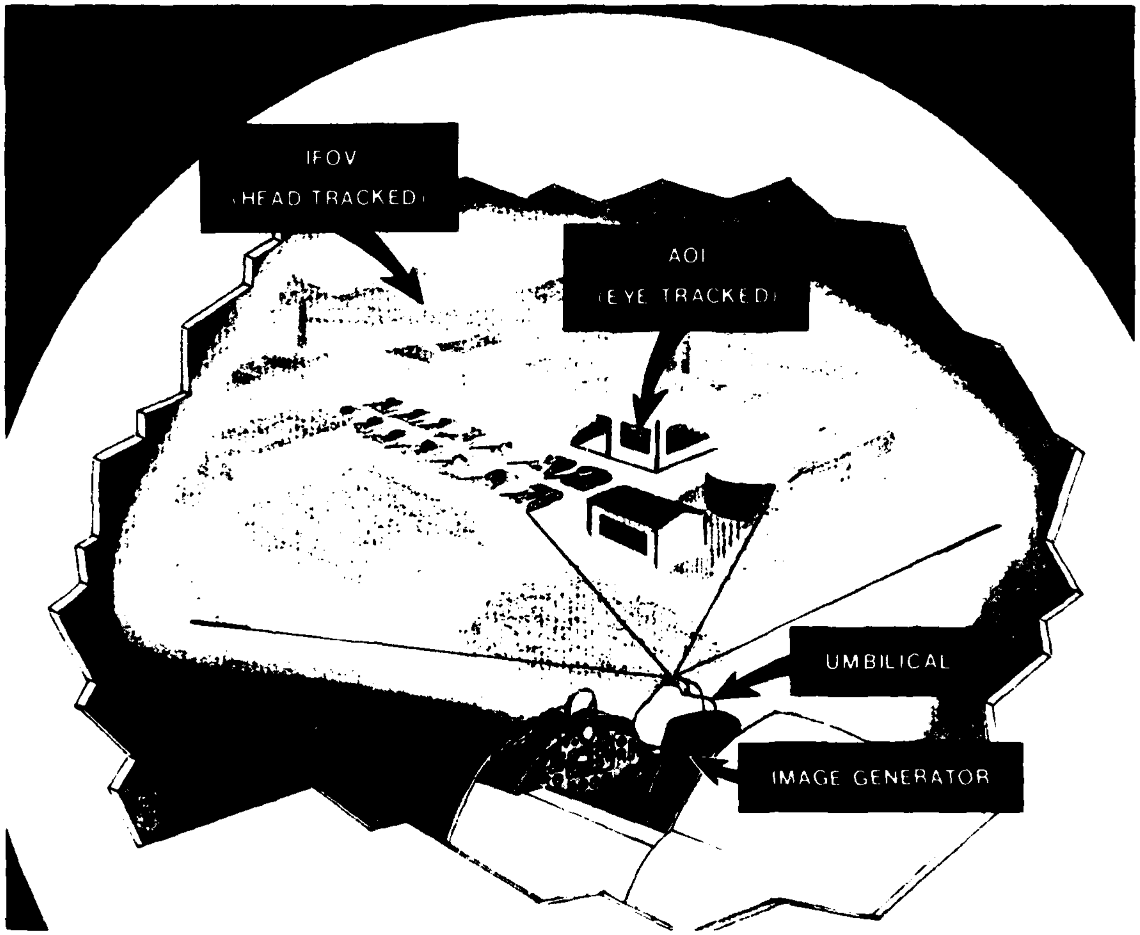

Figure 2. Helmet Mounted Display.

direction. Owing to the rapidly decreasing resolution of the human eye away from the center of vision, such systems have been shown in the laboratory to give the effect of displaying the high detail of the AOI over the whole field of view. The hoped for benefit of adding the AOI concept to the display moved with head direction is an apparent further increase in scene detail with further reduction of image generation costs.

The basic concepts of head and eye tracking to reduce the amount of data to be displayed in real time are by no means new. The Air Force has research programs in which small cathode ray tubes are mounted on the helmet and the image displayed to the pilot. Also, the value of eye tracking is being investigated. The Army is interested in the AOI concept for helicopter simulators and is investigating (with Air Force assistance) the generation of high resolution insets in the displayed scene for representing targets. In the Navy, attention is focused on the use of a scanned laser beam to generate the image—in view of the unique capability of a laser beam to generate a spot of small size and high brightness, and so to permit a tradeoff between high resolution and field of view.

The Visual Technology Research Simulator (VTRS) (Chambers, 1977), previously known as the Aviation Wide Angle Visual Simulator (AWAVS), provides the Navy with a test bed for new visual technology, has a continuing program of human factors work mainly concerned with determining and refining visual display requirements for various tasks in terms of pilot performance, and assists in specifying new visual systems for procurement. The VTRS is shown in Figure 3.

The VTRS Conventional Takeoff and Landing (CTOL) simulator is currently operational and a Vertical Takeoff and Landing (VTOL) simulator is being added. The CTOL system has a simulated cockpit for the T-2C, the Navy's primary jet trainer, mounted at the center of a 10-foot-radius dome screen onto which are projected wide-angle background and narrow-angle target and Fresnel Lens Optical Landing System (FLOLS) images. The dome and cockpit are mounted on a six-degree-of-freedom synergistic motion platform, and motion cues are also available from a G seat. An experimenter/operator station allows interaction with the computer for developing, controlling, monitoring, and recording the experiments.

The CTOL system is at present set up for carrier landing experimental work, the high resolution carrier image being projected by the target projector. Experiments have been completed on factors such as the field of view necessary for carrier landing, the effect of display brightness, CIG lag compensation, the effectiveness of motion system and G seat cues for helicopter precision control (cooperation with NASA, Langley), and the use of additional lights on the FLOLS to give rate cueing and so to markedly improve precision on carrier landing approach. Experimental work will continue, with increasing emphasis on air/ground tasks, through FY 82.

It is worth noting that the display technology developed on the VTRS/CTOL was specified for the ACMS described earlier in this paper, and that it formed the basis of one of two competitive designs selected by the Air Force for future A-10 and F-16 aircraft visual simulation systems for tactical combat training.

The building extension for the new VTOL system has just been completed, and procurement of the hardware and software is in progress. The cockpit will be a simulation of the LAMPS MK III helicopter, and the visual system will have GE color light valve projectors projecting a 160° wide-angle air/ground scene on a dome of similar construction to that of the CTOL. The downward field of view from the horizon will be 50°.

Owing to the non-coincidence of the pilot's head with the point from which the projected beams emerge, the wide-field-of-view ground scene would be subject to distortion. This is being corrected using a new technique in which the CIG computation is modified to produce a predistorted image that looks correct from the pilot's viewpoint.

Planned experiments for VTRS/VTOL include VTOL hover and landing both on ships at sea and in confined areas on land.

Visual R&D Results—Conclusions

The object of the visual research in the VTRS and in the laboratory is to develop cost-effective visual displays that will meet current and future military training requirements that cannot be satisfied by commercially available systems.

As already described, VTRS has produced valuable information to aid the procurement process and this will continue. The systems now emerging

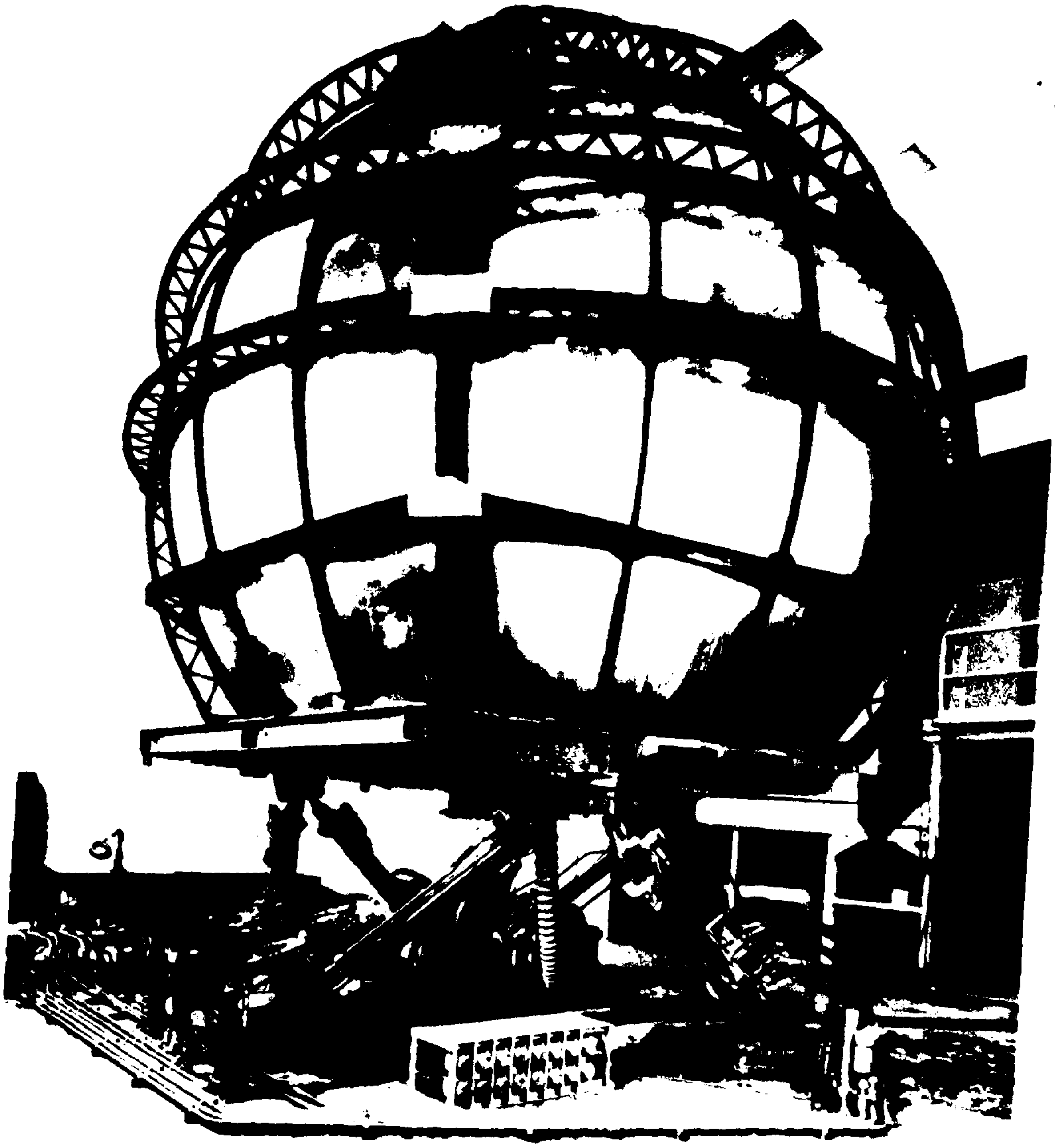

Figure 3. Visual Technology Research Simulator.

from the laboratory will either be set up in VTRS for initial technical and human factors evaluation or subject to risk, timetable, and cost specified for acquisition for training.

The three main new visual developments that have already been described are, briefly:

a. **Laser Visual System (LVS).** The display, on a dome screen, is typically 180° horizontal and 60° to 70° vertical and is in color, with high resolution (approximately five arc minutes per line pair), and without the joins between image segments that exist with multiple projector displays. The image generator uses a high-detail modelboard or several channels of CIG.

This system, available from two major contractors, should be available for procurement within the next 12 months.

b. **Helmet Mounted Display (HMD).** This form of display is suitable only for use with a CIG image generator (two channels only). Its advantages, if the development can be satisfactorily concluded, will be very highly effective image detail for all directions in which the pilot can look, with low cost.

The HMD program calls for the feasibility of a system with the characteristics described to be demonstrated in a year's time, when the building of a full working system could commence.

c. **Advanced Image Generation System.** The investigation of alternative architectures for CIG has led to the definition of an advanced image generation system in which the data base is generated semi-automatically from the Defense Mapping Agency and/or stereo photographs.

The system uses a uniform grid-type digital data base of contoured, textured terrain, as opposed to the polygon-type data base used in presently available CIG systems. The very large data base required is practicable due to the greatly reduced cost of digital bulk stores now available. The image detail is limited only by the display resolution, giving a very large increase in scene detail over what is likely to be available for many years with polygon-modeled CIG.

Software simulation of the images produced by this system will be available within one year. *Subject to funding constraints, a hardware/software design for a complete working system could be ready in two years' time.*

The application of these new visual image generation and display systems depends on many factors; some of these, with the emphasis on cost effectiveness, have already been discussed.

A major problem is the high cost of producing fully working laboratory prototypes of visual systems employing new technology. If the money to allow this to be done in a timely manner is not available, the alternative is to use the experimental results to specify systems for acquisition for training without building a fully working laboratory prototype. However, if the feasibility of the proposed new system has not been fully established by the time the specification is written, there is a risk of time and cost overrun with the procurement. Those factors need careful evaluation in deciding on the best course of action.

In continuing with the developments described, and with the experimental work on VTRS, the perceived future needs of the Navy must be continually updated so that the R&D and acquisition programs will serve these needs at minimum cost.

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